Final Technical Report for Year 1

Grant W911NF-07-1-0663 with the
Newport News Public School District for
the Menchville High School Robotics Team

August 2008

TRIPLE HELIX

Menchville High School
Newport News, VA

DEFENSE TECHNICAL INFORMATION CENTER

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RE: W911NF-07-1-0663

Dear Sirs:

As per the requirements of the subject grant with the Newport News Public School District in Newport News, Virginia, I am submitting to you the final report for year 1 of the grant. As the technical monitor of the grant, I have received the report from the Menchville *FIRST* Robotics Competition team in fulfillment of the grant requirements. Please let me know if there is anything further that the team is required to do to fulfill the terms of the grant.

Sincerely yours,

Matthew L. Wilbur

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Introduction

FIRST (For Inspiration and Recognition of Science and Technology) was founded by inventor Dean Kamen to inspire an appreciation of science and technology in young people. Based in Manchester, New Hampshire, the 501.3(c) not-for-profit organization designs accessible, innovative programs to build self-confidence, knowledge, and life skills while motivating young people to pursue opportunities in science, technology, and engineering. One such program is the *FIRST* Robotics Competition for high school students. In 2008, the *FIRST* Robotics Competition challenged over 37,000 high-school-aged young people on more than 1,500 teams worldwide to work with 18,000 mentors and 2,000 sponsoring companies to design, construct, and test a robot during an intense, six-week season. This six-week season, in which teams must advance from initial design to final product, creates a real world engineering experience that includes critical technical analysis, acquisition and application of engineering knowledge, technical fabrication, systems engineering and integration, time management, resource allotment, teamwork, and many other life skills that combine to help students focus on technology as a possible career choice.

In September 2007, Menchville High School in Newport News, Virginia, with the assistance of a Department of the Army grant and contributions by other non-government entities, established a *FIRST* Robotics Competition (FRC) team. The Menchville Robotics Team, also known as *Triple Helix*, had an outstanding first year. The highlight of the year was participating in the *FIRST* NASA/Virginia Commonwealth University Regional competition held in Richmond, Virginia, March 6-8, 2008. Although placing only 58th out of 64 teams, *Triple Helix* was awarded with the *FIRST* Rookie Inspiration Award for outstanding success in technology education.

Technical Program

The Menchville Robotics Team quickly attracted technical and non-technical mentors from a broad array of organizations in the Newport News area. While many FRC teams struggle with maintaining the support of qualified mentors, Menchville Robotics had no such difficulties. Although a number of the team mentors had dropped out by the end of the build season, which ran from January 5th to February 19th, at the end of the season the team had solidified the participation of the following mentors:

Gary Bayless, Engineering Technician, Jacobs Engineering
Wardell Boyle, Teacher, Newport News Public School
Dr. Walter Deal, Professor, Old Dominion University
Yolanda Hinton, Mechanical Engineer, US Army Research Laboratory
Chester Langston, Electronics Engineer, US Army Research Laboratory
Dr. Anton Riedl, Assistant Professor, Christopher Newport University
Justine White, Teacher, Newport News Public Schools
Matt Wilbur, Research Engineer, US Army Research Laboratory
Laura Wilbur, Physical Therapist Assistant (Non-engineering mentor), Self-employed
Bill Yeager, Aerospace Engineer, US Army Research Laboratory (Retired)

Student recruitment began early in the school year, with the first team meeting scheduled for two weeks after the students reported back to school. Student recruitment consisted of posters

describing *FIRST*, the enjoyment of designing and building a robot, and the thrill of competing at the events. Approximately 30 students attend the team's first meeting; however, a desire to compete in more destructive robotics competitions such as Battle Bots quickly trimmed the team to 15 students. The period from late-September through mid-December was dedicated to teaching the students what they needed to know to become a functioning member of a competitive robotics team. This was accomplished primarily by using Vex robotics kits, which are Erector-Set-scale robotics kits. These kits, although small scale, incorporate almost all of the features of the large scale FRC robots, including controllers, sensors, and drive trains. The mentors also worked with the students to sub-divide them into design, fabrication, electronics, and programming teams according to their particular skill sets. During this time, the team worked to develop an identity. Following weeks of deliberations, the name *Triple Helix* was chosen and the team logo developed to emphasize a man-machine interface at the deepest levels of human development. The team logo, presented in figure 1, represents the merger of the double helix of the human DNA with a single strand of "robotic DNA" represented by the type of roller chain commonly used in *FIRST* robot drive trains. The team motto that was selected further emphasized the team identity by exclaiming, "It's in our genes!"

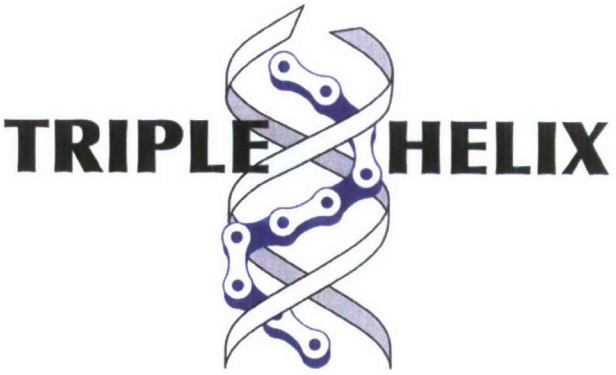

Figure 1. The Menchville High School Robotics Team logo.

The *FIRST* Robotics Competition Kick-Off was held on January 5, 2008, in Manchester, New Hampshire. The event was broadcast by NASA TV to satellite facilities around the world. *Triple Helix* watched the event along with two other FRC teams at the Virginia Air and Space Center in Hampton, Virginia. The *FIRST* game for the season was announced to be *FIRST:* Overdrive, a racing game in which robots received points for maneuvering around a Track and received bonus points for manipulating a 40-inch diameter exercise ball called a Trackball. Rather than the traditional 15 second autonomous round at the beginning of each match, this year the teams were challenged with "hybrid" mode, in which a team member could communicate with the robot through the use of a conventional infrared television remote. Following this, a 2-minute teleoperated period permitted students to control the robots through the completion of the match.

The robot design that *Triple Helix* chose to implement permitted both ball manipulation and scoring by running laps. The Trackballs, in addition to being the large 40-inch diameter, were covered with slick cloth and weighed approximately 7.5 lbs. Therefore, determining a feasible

method for manipulating the Trackball represented the bulk of the design time. In order to score the maximum number of points, the Trackball had to be "hurdled" over a 6-ft, 6-inch tall Overpass structure near the center of the Track (see figure 2). The solution selected by the team utilized a large gripper designed to cradle the Trackball, and the combination of an elevator system and four-bar mechanism to reach above the Overpass structure. The completed *Triple Helix* robot, named "Snowflake", is presented in figure 3.

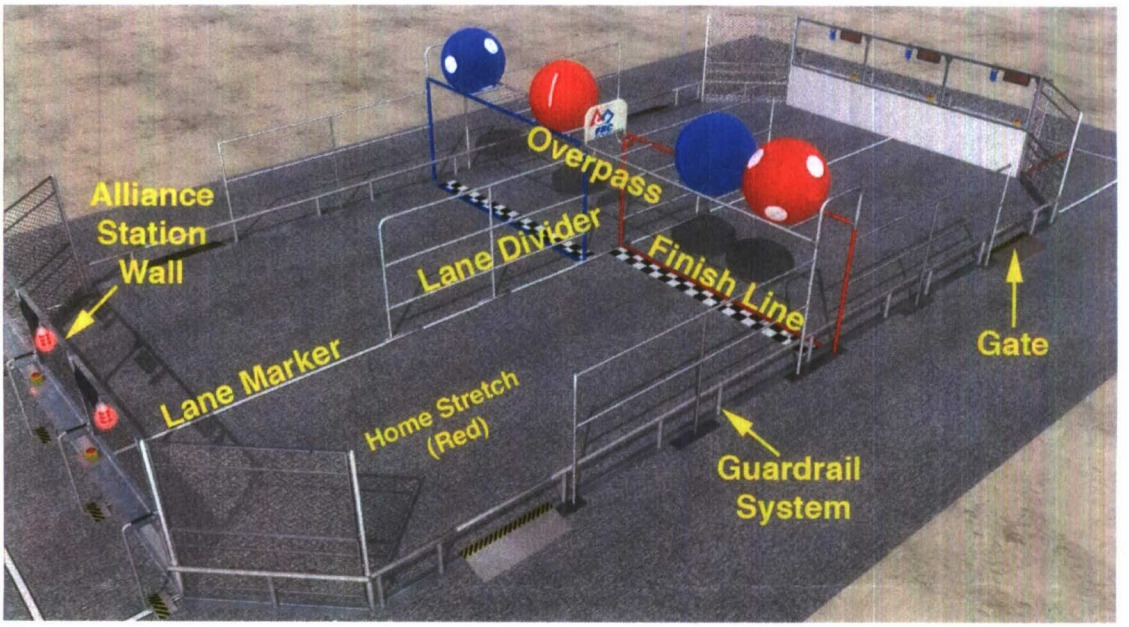

Figure 2. The Track layout for *FIRST:* Overdrive showing the Overpass structure and the Trackballs. The Track is a region 27 feet wide by 54 feet long.

The robot incorporates a chain-driven, 4-wheel drive chassis that utilizes tank-style steering, otherwise known as skid steering. With this approach a turn to the left is accomplished by leaving the left side wheels stationary and driving the right side wheels forward. A sharp turn to the left can be accomplished by driving the left side wheels backwards while simultaneously driving the right wheels forward. Driver steering was accomplished with two traditional computer joysticks – one to operate the right side wheels and the second to operate the left side wheels. In this manner, the student driver could push both joysticks completely forward to achieve the maximum forward robot velocity or pull both joysticks backwards to drive at top speed in reverse. A second student operated the elevator, 4-bar mechanism, and gripper with a third joystick.

The robot design incorporates an Innovation First, Inc., robot controller and operator interface. This system functioned as the "brain" and control interface for the robot. The drive system utilizes four high-power DC motors producing a combined maximum power of nearly 2 HP. A single speed transmission is used to drive the roller chains that power the wheels. The speed of the drive train motors is controlled through the use of a speed controller, each of which are commanded with a Pulse Width Modulation train generated by the robot controller in response to commands from the hybrid mode programming or the operator interface system. The elevator

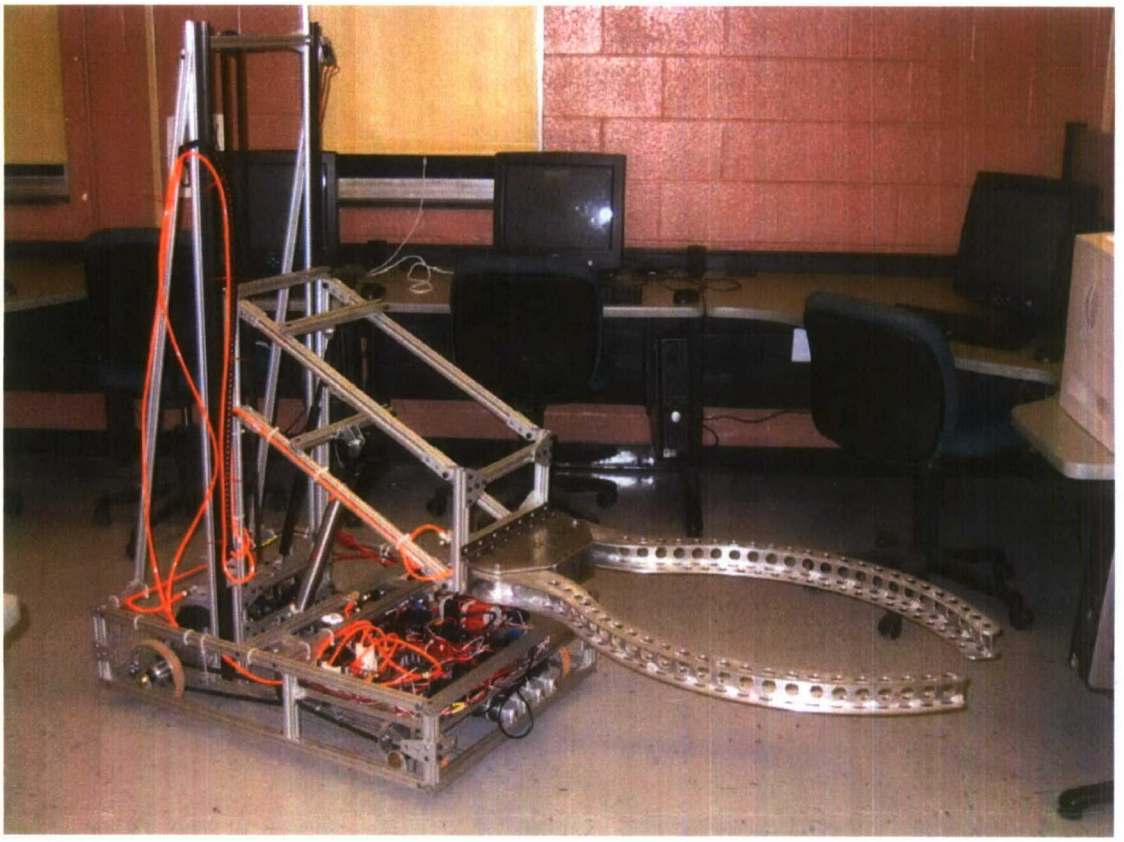

Figure 3. The *Triple Helix* robot for the 2008 *FIRST* Robotics Competition.

system employs a Fisher-Price drive motor and gear reduction set from their popular PowerWheels line of products. This drive system operates a chain looped over a sprocket on the upper portion of the elevator tower, thereby providing the motivating force to lift the elevator mechanism. The elevator is constrained to a track using an Igus linear bearing system. The final components are the four-bar mechanism and the Trackball gripper, which are both controlled pneumatically. A pneumatic compressor is placed in the rear of the robot, with air storage tanks and servovalves installed elsewhere within the robot. Hydraulic tubing is run throughout the robot to control the two-way cylinders connected to the four-bar mechanism and the gripper. To permit the elevator to fully extend while maintaining the integrity of the pneumatic tubing, an Igus Energy Chain helps to avoid kinks or damage. To assist with balancing the weight of the gripper, a gas strut is employed between the elevator and the four-bar mechanisms. Finally, the gripper is actuated with a straightforward push-pull linkage system. The gripper is hinged to the front of the four-bar mechanism so that it can be folded up and stowed in place vertically at the beginning of a match. This is required in order to meet the maximum dimensional requirements for the robot at the start of the match, which are 38 inches by 28 inches by 60 inches.

The robot design was accomplished by the students with assistance from the team mentors. The first several weeks of "build" season were dedicated to conceptual and detailed design. The most challenging time for the mentors was during the conceptual design phase when the students would come up with "cartoon" type designs utilizing dozens of joints and actuators. Keeping the

students on task was challenging, however, with careful coaching the students were generally able to make informed design decisions. One mentor developed a number of robotic arm prototypes made out of wood to demonstrate different design candidates. Based on their inspection of the various designs, the students chose the four-bar mechanism as a central component of the robot and selected the manner in which the gripper would be actuated. With these design constraints in hand, the choice of an elevator as the final aspect of the device design was clear; otherwise, the robot could possibly exceed the maximum dimensional constraints required by the rules.

The robot chassis is fabricated from 80/20 brand extrusions and fittings. The students cut and assembled all components of the robot with assistance from the fabrication mentors. Identification of robot components required for completion was performed jointly by the students and the mentors. The complex gripper design was modeled in CAD and submitted to Eagle Aviation Technologies, Inc. (EATI), a small engineering firm in Hampton, Virginia. EATI had agreed to sponsor the team by fabricating components that required specialized milling machines. EATI completed milling the various gripper components and a second engineering firm, Advanced Technologies, Inc., in Newport News, Virginia, provided welding services.

Results

During the course of the school year, the students learned skills in the following areas:

1. Electronics – Proper soldering and crimping techniques, electronic board layout and design, debugging techniques, and proper sensor package connectivity
2. Pneumatics – Fundamental pneumatics component physics and design, pneumatic component selection and sizing criteria, leak detection, and debugging techniques
3. Mechanical design – Motor criteria and power, gear ratios, basic static and dynamic loads and control requirements, and kinematics. Students utilized Autodesk Inventor CAD software to visualize components and to observe how they fit together.
4. Fabrication – Safe power tool usage techniques for band saw, drill press, miter saw, and bench grinders; eye and hearing protection; 80/20 extrusion assembly; proper drill and tap techniques; and custom component fabrication
5. Software – Real-time robot software and control techniques, autonomous mode programming techniques, complex sensor package programming, and debugging techniques. Students utilized Intelitek EasyC and conventional C compilers.

Time management was also a critical lesson learned because there was still much work to be done to complete the robot by the end of the weekend prior to the robot shipping date. By rule, robots had to be shipped on February 19, 2008, in order to qualify to compete in the *FIRST* events. The *Triple Helix* robot was completed at 11:00pm on February 18, 2008, but no real testing of the robot had been completed. Also identified during the final hours of the build season was a weight problem. By rule the robots were limited to a weight of 120 lbs. The robot was identified to weigh 126 lbs with no time remaining to address the issue. Beginning two weeks prior to the end of build season, team mentors began suggesting that the team consider adding a few hours to the work schedule in order to ensure that the robot would be completed on

time. The students seemed disinterested in this prospect until the night before shipping, at which time they realized that it was too late -- but learned an important lesson in the process.

During the period of Thursday, March 6th through Saturday, March 8th, *Triple Helix* participated in the *FIRST* NASA/VCU Regional event held in Richmond, Virginia, at the Virginia Commonwealth University basketball arena, the Siegel Center. For all *FIRST* Robotics Competition events, the team is permitted access to their robot early on Thursday morning at the competition site. The team is provided a pit area of approximately 100 sq. ft., which the team works to set up on Thursday morning. Since the *Triple Helix* robot was overweight, eliminating the excess weight was of primary importance, and engaging in practice rounds throughout the day was considered to be of secondary importance. All robots competing must undergo a thorough inspection process in order to qualify for the competitive rounds that begin on Friday morning. The *Triple Helix* robot had modifications made to it and met all inspection requirements by late Thursday afternoon. The team did manage to participate in several practice matches throughout the day.

On Friday, *Triple Helix* was honored to be a participant in the first match of the day, which meant that our robot was displayed on the field during the competition opening ceremonies. Matches are played with three teams, chosen at random, forming an "alliance" to compete against a second alliance of three teams. *Triple Helix* competed in the qualification matches throughout Friday and on Saturday morning, ending up with a disappointing record of 2 wins and 6 losses. Throughout it all, however, the students and mentors kept fighting through problems to field the most competitive robot possible. By the end of the qualification matches the robot was generally in good shape, the team having resolved most of the problems that were identified during the competition. Most of the difficulties with the robot were with the drive train, which was not as maneuverable as had been anticipated. This led to difficulties in acquiring and manipulating the Trackballs as the robot moved around the track. All of the teams competing also found that it was very easy to commit a penalty for which there were severe point reductions, and having a robot that was not very maneuverable meant that *Triple Helix* incurred a number of penalties throughout the competitive rounds.

On Saturday, the qualification matches continued. These qualification matches developed a set of seeds that ranked the robots in order of performance. *Triple Helix* ended up ranked 58th out of 64 teams. At noon, the top eight teams selected two additional teams from the remainder of the field to compete in their alliance during the elimination matches. To move to the next round during the elimination matches, an alliance must win two out of three matches against the opposing alliance assigned to them. Matches progress from quarter-finals, to semi-finals, to finals to determine the eventual champion alliance of the competition. Unfortunately, *Triple Helix* was not chosen to compete as an alliance member in the elimination matches.

Late on Saturday afternoon, the awards ceremonies began. Awards are given out for various categories including engineering design, novel control concepts, community service, etc. *Triple Helix* was honored by receiving the Rookie Inspiration Award, which noted the team's perseverance through difficult times and a commitment to advancing the respect for engineering and engineers both within the school and the community. Considering that there were eight very

good rookie teams registered at the competition, the team was extremely excited to have won this prestigious award.

Following the competition, the robot was shipped back to Menchville High School. To their credit, the students were greatly interested in digging back in, resolving problems with the robot, and identify areas for improvement. The team spent the bulk of the spring making improvements to the robot and seeking opportunities for community outreach. We attended two different events during the spring, bringing the robot with us to demonstrate for the public to see. The first was at an open house at Crittenden Middle School in Newport News. Crittenden is the only middle school in Newport News to have a *FIRST* Lego League team, and they were excited to have the chance to see our large FRC robot in action. We also attended the Newport News Children's Festival of Friends, which was held at Newport News Park on May 3, 2008. As part of this event, we demonstrated our robot and spent the day telling the public about our robot, what we learned from our experience with *FIRST*, and simply getting the children excited about robots and technology.

Future Plans

With the school year ending and the school facility being closed for heating and air conditioning overhauls over the summer, *Triple Helix* shut down operations in early June. An end of year picnic and awards ceremony was held, an event that most of the students and mentors attended. Of the nine students who completed the year as members of *Triple Helix*, five of them were graduating seniors; therefore, only four of the students from the 2008 team will be returning for the 2009 FRC season. Thus, heavy student recruitment efforts are being planned for September when the students return to school, and it is anticipated that there may be a large contingent of freshmen on the team. While challenging, this is considered to be good in terms of the long term development of a highly competitive team.

The grant funding supplied to *Triple Helix* by the US Army Research Laboratory is generally sufficient to field a team each year. Funds are utilized to pay the FRC registration fees, which include a kit of robot components, the additional cost of components required to fabricate a complete robot, and to institute a capital investment plan where new long-term equipment is purchase each season. Under the current structure, team travel expenses are paid by fundraising, student/parent contributions, and/or other sponsoring organizations. The team plans to attend an off-season event in the fall called the "Robot Rumble," which will be held at the State Fair of Virginia during the first weekend in October. Provided that sufficient funding is generated through additional sponsorships and fundraising in the fall, the team will sign up for two regional events for the regular season in the spring of 2009.

Triple Helix is also committed to community outreach and sponsoring *FIRST* teams at the Junior *FIRST* Lego League (JFLL) and the *FIRST* Lego League (FLL) levels in elementary and middle school. As such, the team currently plans to reserve 10% of the funds raised during fundraising activities to help sponsor new teams in the region. The team is also working towards offering robotics summer camps beginning as early as 2009, in order to introduce young people to the rewards of robotics.

Finally, *Triple Helix* is partnering with a number of organizations to develop an interest in *FIRST* and its programs throughout the Hampton Roads area. We have crafted a relationship with the Hampton Roads Technology Council, and currently have information on their website at www.hrtc.org/FIRST. We have also worked with the local chapter of the Association for Unmanned Vehicle Systems International (AUVSI) and an exploratory organization known as Robot Venture, which seeks to make the Hampton Roads region a nexus for robotics and unmanned systems technology. We are also working with the regional director of Virginia*FIRST* to establish a network of *FIRST* teams in Hampton Roads. We are proposing to call this organization Hampton Roads *FIRST*, and hope to use it as a tool to permit FRC team collaboration, aid in the sustenance of teams, and spread the word about *FIRST* to the citizens of Hampton Roads.